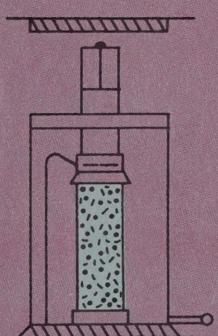
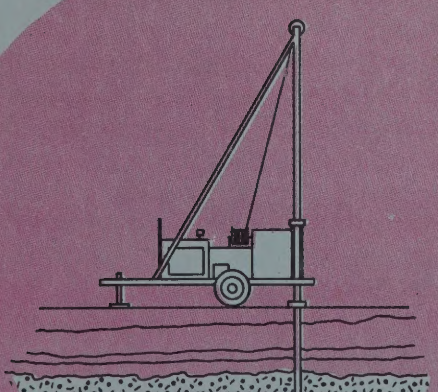
STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION

SOIL MECHANICS BUREAU





PROCEDURE FOR DETERMINING THE RATIO OF THE HORIZONTAL TO VERTICAL COEFFICIENT OF CONSOLIDATION BY MEANS OF THE BLOCK PERMEABILITY TEST

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SM 238b (1/73)

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1. SCOPE

1.1 The purpose of the block permeability test is to determine the ratio of the horizontal to vertical coefficient of permeability, k_H/k_V, on the same sample using the falling head method. The k_H/k_V ratio is identical to the ratio of the horizontal to vertical coefficient of consolidation, C_H/C_V.

2. SIGNIFICANCE AND USE

2.1 The block permeability test is a falling head test capable of measuring the vertical as well as the horizontal permeability on the same sample.

2.2 The test equipment will specifically be used in the determination of the ratio of horizontal to vertical permeability, k_H/k_V, which is identical to the ratio of the horizontal to vertical coefficient of consolidation, C_H/C_V. The C_H/C_V ratio is vital for the inclusion of horizontal drainage effects in the determination of time rate of settlement of loaded foundations and for the determination of spacing of vertical sand drains used to accelerate foundation settlements. The tests are run in a modified high pressure triaxial cell which allows consolidation of the sample and the use of a high back pressure to eliminate the effects of air or gasses.

3. SUMMARY OF METHOD

3.1 The development of this test required the fabrication of special pieces of equipment such as a square base pedestal, square top cap, a membrane former, a membrane stretcher, and sample trimmer.

3.2 The block permeability test procedure and test apparatus now used in the Bureau (see Figures 1,2) are similar to the permeability test developed

at M.I.T. by Ladd and Wissa. (1)

3.3 The vertical and horizontal permeabilities are achieved on the same sample (in cube form) by rotating the sample into the proper plane.

3.4 Two clear graduated cylinders are used to measure the flow of water into and out of the sample.

4. APPARATUS

4.1 A high pressure triaxial chamber was modified by replacing the conventional circular base pedestal and top cap with a base and cap machined out of acrylic resulting in a 2-3/8 inch square cross section transitioning to a cylinder having a diameter slightly less than 2.3 inches. (Fig. 2.) A 2 inch square base and cap system was also fabricated for use with samples extruded from a 2-3/8 inch shelby tube or brass liner.

4.2 The membrane (Fig. 4) used in this test is not commercially available and must be made using a special shaped former and liquid latex. The former was machined out of acrylic and it conforms in shape to the top cap, sample cube, and bottom base. However, it is slightly smaller in dimension thus ensuring a snug fit and seal.

4.3 The membrane stretcher (Fig. 3) consists of a square acrylic tube with a longitudinal groove located in each corner of the tube extending from the top to the bottom. These grooves are interconnected around the outside perimeter of the acrylic tube by means of 1/4 inch tee fittings and 1/4 inch

(1) Ref. S. K. Saxena, J. Hedbery, C. C. Ladd, Results of Special Laboratory Testing Program on Hackensack Valley Varved Clay, June 1974, Research Report R74-66 Soils Publication 342, Department of Civil Engineering, Massachusetts Institute of Technology.

plastic tubing at each outside corner. The 1/4 inch tubing is connected to a vacuum source which expands the membrane when it is to be placed on or removed from a sample.

4.4 The sample trimmer (Fig. 5) consists of a rotating base mounted on a 2 inch high pedestal which is permanently located between four 3/8 inch vertical rods. The vertical rods are guides for the wire cutter used to trim the sample. Each set of rods is labeled to correspond with the size sample to be trimmed. A spring loaded locking pin mounted on the side of the pedestal engages the rotating base every 90 degrees.

4.5 The following are required general equipment in addition to those previously mentioned:

a) Two 200 psi gauges with a 0.25 percent full scale accuracy.

b) Two 200 psi regulators.

c) Two clear 1 inch I.D. cylinders graduated in centimeters and tested to a pressure of 180 psi. These are used to measure the flow of water into and out of the sample and are referred to in this text as reservoirs.

5. TEST PROCEDURE

5.1 Review the x-ray film of an undisturbed sample tube to select the sample to be tested. (All undisturbed sample tubes and drive liners used for testing by the Soil Mechanics Bureau are x-rayed prior to the extrusion of any material).

5.2 After extruding a selected three inch sample from the undisturbed sample tube, the sample is placed on the rotating base of the sample trimmer (Fig. 5) and is trimmed to a 2-3/8 inch or 2 inch square using a wire cutter and rotating the base 90 degrees four times.

5.3 An acrylic tube (Fig. 6) 2-3/8 inch or 2 inches in height and 2-1/2 inch square inside is carefully placed over the sample. The sample and acrylic tube are then removed from the base and placed on a countertop to finish trimming the top and bottom to a 2-3/8 inch or 2 inch length. The sample should be weighed and then measured using calipers. The before and after measurements will give an indication of any volume change.

5.4 The top and bottom stones are flooded with de-aired water. This is accomplished by opening the valves to the stones and applying a slight back pressure. As soon as both stones are flooded, filter paper (Eaton-Dikeman, Grade 615) cut to size is placed on both stones. Next, the sample, orientated in the vertical direction, is placed on the base. Then the top cap and stone is placed on the sample with the quick-disconnect uncoupled (the fluid line from the chamber base to the top cap contains a quick-disconnect, which allows for disconnecting the top stone during the application or removal of the membrane).

5.5 The membrane is placed in the stretcher and the vacuum applied. Next, the membrane and stretcher are slowly lowered over the sample, and at the proper position, the vacuum is turned off allowing the membrane to leave the stretcher and encompass the sample, top cap, and base. The stretcher is removed and the membrane is sealed top and bottom using flat rubber bands. The quick-disconnect is reconnected and the triaxial chamber is carefully lowered over the sample and locked in place. The chamber is then filled with a sufficient amount of water to cover the top cap and quick-disconnect.

5.6 The confining and back pressures are placed on the sample in 10 psi increments, never allowing the back pressure to exceed the confining pressure. Each increment is allowed to consolidate and the water levels in the reservoirs

are recorded. The maximum confining pressure is 150 psi and the maximum back pressure is 100 psi.

Note: The level of the chamber fluid should be marked and it should be checked prior to increasing to the next increment. A drop in chamber fluid indicates leakage in the membrane.

5.7 After the sample has been allowed to consolidate at the last increment, the valves to the top and bottom stones are closed and the two reservoirs are then moved into position to conduct the falling head permeability phase of the test. The reservoir connected to the bottom stone is elevated above the sample chamber and the reservoir connected to the top stone is lowered below the elevation of the sample chamber. Thus the flow of water will be from the bottom of the sample to the top, forcing any trapped air out.

5.8 The initial water level of each reservoir is recorded and the valves are then re-opened. The changing water levels are recorded at 1/2 hour intervals until both reservoir levels change consistently. When this occurs, the distance (or initial head) between the two reservoir water levels is measured and recorded with time. The water levels are then recorded from this point, at 1/2 hour intervals for at least 24 hours.

5.9 At the completion of the vertical phase of the permeability test the system is shut down. The stone valves are closed, the air pressure is bled off, the reservoirs are returned to the counter, and after the chamber fluid is removed, the chamber is removed from the base.

5.10 The top stone is disconnected from the system and the membrane stretcher is placed over the sample. The top and bottom of the membrane is then placed on the stretcher with the vacuum on. Upon release of the membrane from the sample, the top cap is removed, after which the membrane and stretcher are removed from the sample and base.

5.11 The sample is measured in the horizontal axis, using calipers, prior to removing the sample from the base and in the vertical axis after the sample has been removed from the base. These measurements are used to compute volumetric change.

5.12 After the sample is measured steps 4 through 11 are repeated for the horizontal phase of the permeability test with the rotated sample placed on the base, i.e., the horizontal layers of the sample being in a vertical direction.

5.13 Upon completion of the horizontal phase and sample measurements the sample is weighed and oven dried for a final M.C.

6. CALCULATIONS

6.1 The permeability is computed using the formula given below:

$$k_h \text{ or } k_v = \frac{C}{T} \operatorname{Log}_{10} \frac{H_i}{H_f}$$

Where: k_h = horizontal permeability cm/day

k_v = vertical permeability cm/day

T = time (hrs.) from the initial head to the final head, starting when Section 5.8 conditions are met.

H_f = final head, computed (see Fig. 7)

H_i = initial head, measured

C = a constant - 46.3 for a 2-3/8 inch size sample and 55.1 for a 2 inch size sample. These C's are derived from the following:

$$C = 2.3 \frac{aL}{A} \times 24 \text{ hrs/day}$$

Where: a = cross-sectional area of the reservoir 1 in. dia. - 5.06 cm^2

A = cross-sectional area of the soil sample,

- 36.42 cm^2 for a 2-3/8 in. size sample

- 25.83 cm^2 for a 2 in. size sample

L = length of soil sample - 6.03 cm for a 2-3/8 in. sample

- 5.09 cm for a 2 in. sample

See Fig. 8 for block permeability data sheet, SM 447.

7. REPORT

7.1 The report of test results shall be made up of the following:

7.1.1 The identification of the project, Project Identification Number, hole number, sample number, and sample depth.

7.1.2 A visual description of the soil tested.

7.1.3 Any variations from the method described in this procedure.

7.1.4 The results as computed for the horizontal and vertical coefficients of permeability.

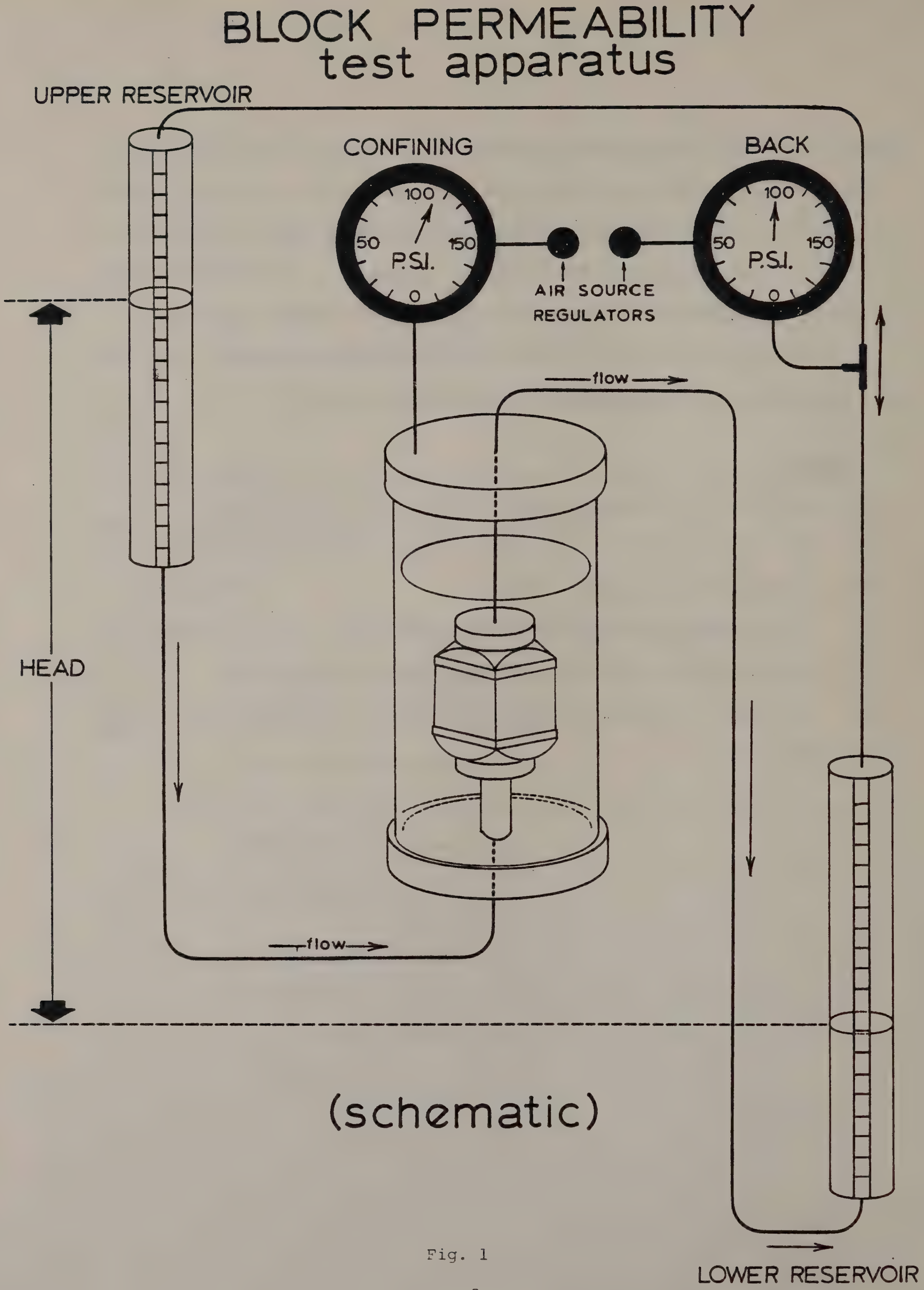
BLOCK PERMEABILITY
test apparatus
UPPER RESERVOIR
CONFINING
BACK
100
50
150
P.S.I.
0
100
50
150
P.S.I.
0
AIR SOURCE
REGULATORS
flow
HEAD
flow
(schematic)
LOWER RESERVOIR

Fig. 1

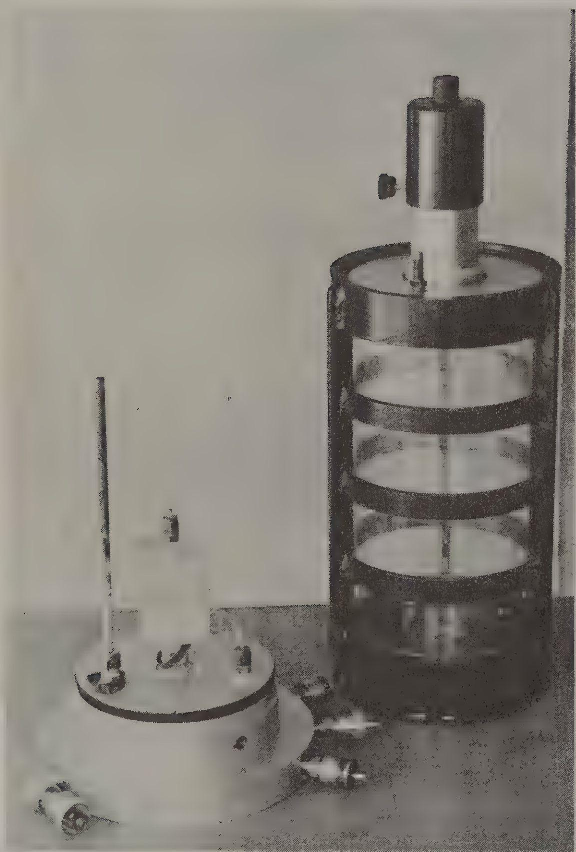

FIG. 2 - Base pedestal and top cap mounted on chamber base (l.), chamber (r.).

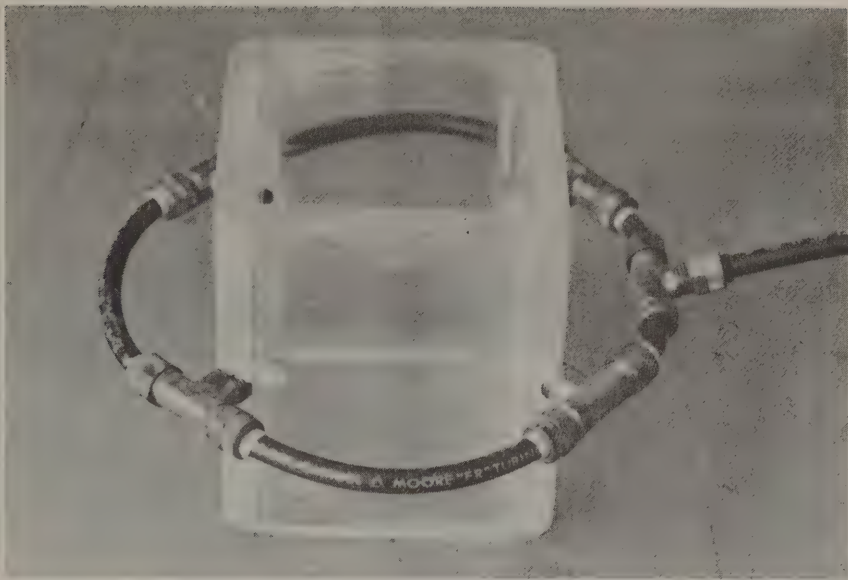

FIG. 3 - MEMBRANE STRETCHER. Rubber membrane is placed inside and pulled over top and bottom edges of stretcher. Vacuum is then applied, pulling membrane outward.

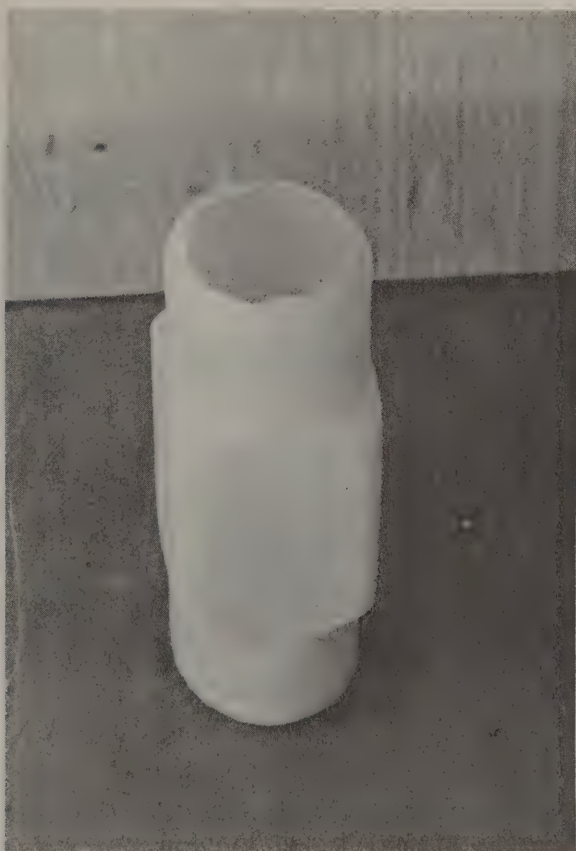

FIG. 4 - RUBBER MEMBRANE

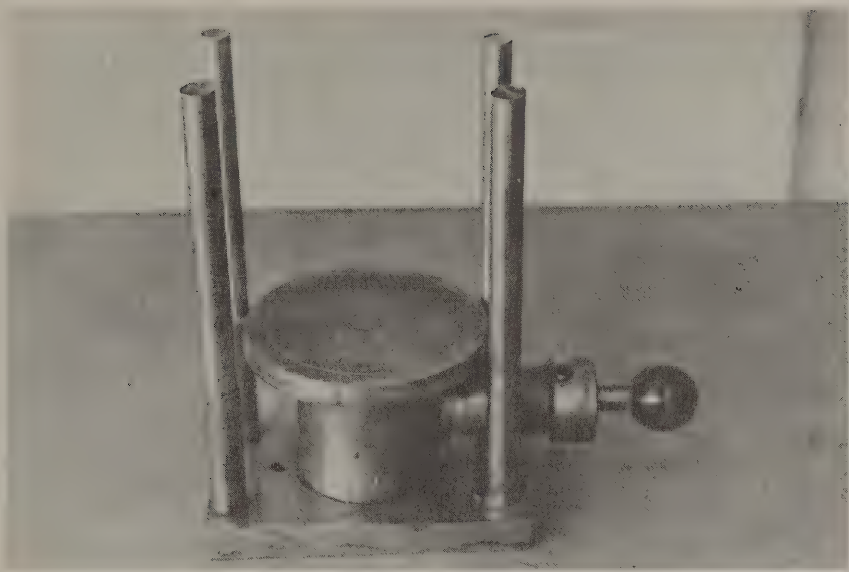

FIG. 5 - SAMPLE TRIMMER. Front rods are used to trim 2-3/8 inch sample; rods in back for 2 inch sample. Engraved line is for smaller diameter sample.

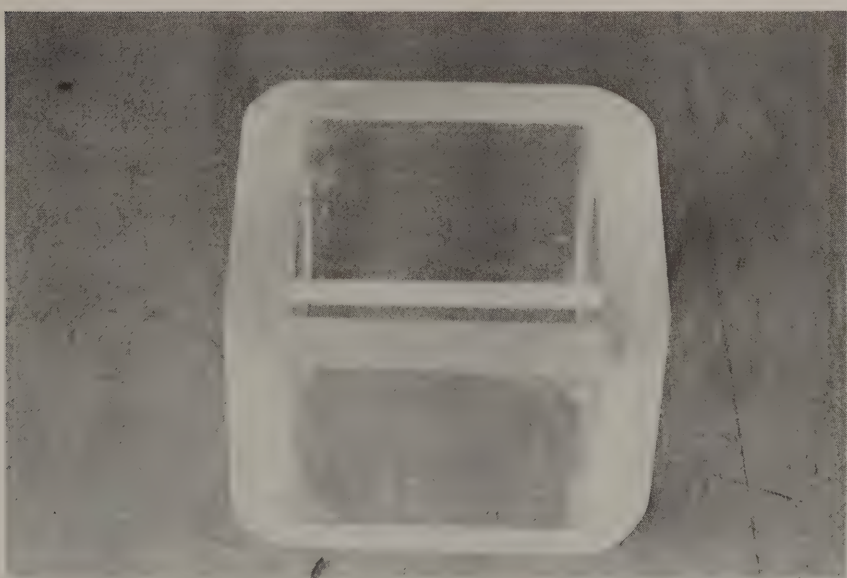

FIG. 6 - ACRYLIC TUBE. I.D. is oversized to fit over trimmed sample. Lay tube and sample on side to trim cube.

BLOCK PERMEABILITY TEST
(FALLING HEAD)

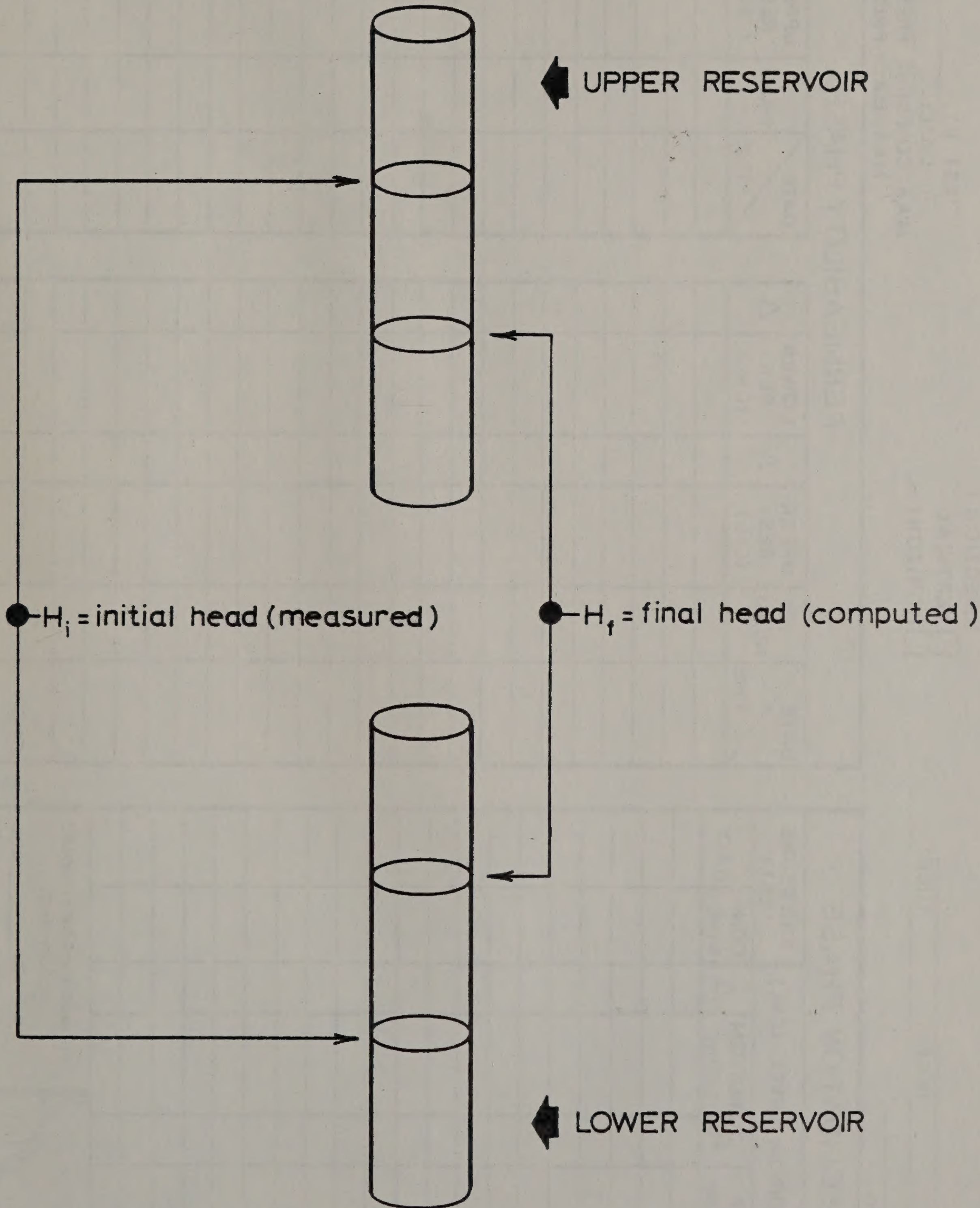

FIG. 7

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BLOCK PERMEABILITY

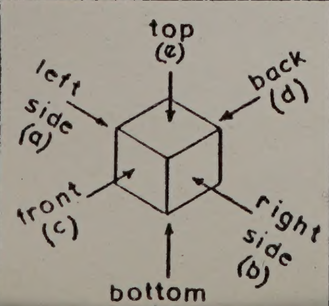
PROJECT: ____________________
P.I.N.: ____________ HOLE: __________ TUBE: _____
DEPTH: ____________
DESCRIPTION: ____________________

DIRECTION:
☐ VERTICAL
☐ HORIZONTAL

TEST BY: ____________________
DATE: ____________________
MAX. CONFINING PRESSURE ______ P.S.I.
MAX. BACK PRESSURE ______ P.S.I.

CONSOLIDATION PHASE

DATE / TIME	RESERVOIR LEVEL (CM.)				PRESSURE (P.S.I.)	
	TOP STONE	Δ	BOTTOM STONE	Δ	CON-FINE	BACK



sample measurements:
before test
a↔b: ________ cm.
c↔d: ________ cm.
e↔f: ________ cm.
after test
a↔b: ________ cm.
c↔d: ________ cm.
e↔f: ________ cm.

PERMEABILITY PHASE

DATE / TIME	HEAD	UPPER RES. (CM.)	Δ	LOWER RES. (CM.)	Δ

DATE / TIME	HEAD	UPPER RES. (CM.)	Δ	LOWER RES. (CM.)	Δ

Fig. 8